UNIVERSITY OF SOUTHERN QUEENSLAND

Development and characterisation of an ultra-long exposure UV dosimeter

A dissertation submitted by

Abdurazaq A. A. Amar

BSc. (Physics), MSc. (Applied Physics)

For the award of

Doctor of Philosophy

2014

Abstract

Excessive exposure to solar ultraviolet (UV) radiation is known to have detrimental effects on human health, some of which are cumulative in nature with impacts that may arise after years and decades of exposure. Therefore, it is important that the risk associated with prolonged UV exposure can be investigated; this requires long-term studies in which large-dose measurements can be accurately quantified.

Chemically-based UV dosimeters have been widely used to measure personal UV exposure since 1976. Despite the development of electronic UV dosimeters, chemical dosimeters maintain their suitability in human exposure research as versatile, labour- and cost-effective UV monitors that require no power. The main limitation of existing chemical dosimeters is their short dynamic measurement range, as they are saturated after relatively short exposure times. Consequently, prolonged personal UV exposures are estimated either from measurements spanning just a few days, with high uncertainty, or by the regular replacement of dosimeters on location, a practice that increases the cost and effort. A dosimeter that continuously measures longer periods would facilitate the task and provide more reliable estimates of prolonged UV exposures.

A new chemical UV dosimeter that meets this demand was developed and fully characterised in this study. The dosimeter, composed of unstabilised solvent cast polyvinyl chloride (PVC) in 16 μm thin film, is able to measure at least three weeks of full day exposure to solar UV radiation under clear sky conditions in summer at subtropical sites. This is twenty times the dose capacity of the most commonly used chemical UV dosimeter, a polysulphone based UV dosimeter.

The optimal parameters of the dosimeter's construction and its dosimetric properties were experimentally investigated and characterised. The results show that the proposed dosimeter is easy to prepare, inexpensive, physically robust and easily analysed using an FTIR spectrometer. It responds mainly to UVB radiation, and hence can be calibrated for quantifying erythemally effective doses for long-term personal exposure studies. The response of the dosimeter to solar UV radiation is independent of temperature and dose rate. It also, exhibits an acceptable angular-error (defined as the deviation of the dosimeter's relative response from the cosine function when the angle of incident beam is changed) and almost no dark reaction.

A field test was conducted to validate the proposed dosimeter with long-term personal UV exposure measurements. The erythemal UV exposures to selected anatomical sites on rotating head form manikins measured with the PVC dosimeter agreed well with the measurements obtained concurrently by a lower dose capacity chemical UV dosimeter, and are on a level with the results reported in earlier similar studies.

The characterised dosimeter is a valuable tool for research on the latent effects of cumulative UV exposure on human health. Measurements over longer periods will provide more reliable annual and lifetime exposure estimates as the larger the sample size (length of measurement period), the more accurately the sample will present the population (annual or lifetime UV exposure).

Certification of Dissertation

The research contained in this dissertation is the full documentation of the research results that are published and presented as

1. Amar, A & Parisi, AV 2012, 'Investigation of unstabilized polyvinyl chloride (PVC) for use as a long-term UV dosimeter: preliminary results', *Measurement Science and Technology*, vol. 23, no. 8, pp. 1-7.
2. Amar, A & Parisi, AV 2013, 'Spectral response of solvent-cast polyvinyl chloride (PVC) thin film used as a long-term UV dosimeter', *Journal of Photochemistry and Photobiology B: Biology*, vol. 125, pp. 115-20.
3. Amar, A & Parisi, AV 2013, 'Optical properties of a long dynamic range chemical UV dosimeter based on solvent cast polyvinyl chloride (PVC)', *Journal of Photochemistry and Photobiology B: Biology*, vol. 128, pp. 92-9.
4. Amar, A and Parisi, AV. (2012) *Investigation of unstabilized polyvinyl chloride (PVC) for use as a long-term UV dosimeter: preliminary results.* In: 37th Annual Conference of the Australasian Radiation Protection Society (ARPS 2012): Radiation Safety: Bridging the Gap, 14-17 Oct 2012, Sydney, Australia.

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

_____ _____

Signature of Candidate Date

ENDORSEMENT

_____ _____

Signature of Principal Supervisor Date

_____ _____

Signature of Associate Supervisor Date

Acknowledgements

I would like to express my deepest gratitude and respect to my principle supervisor, Professor Alfio Parisi, for his excellent guidance, patience and care, and for providing me with valuable advice and suggestions throughout the research.

I would like to thank the Libyan Government through the Higher Education Ministry and Azzawia University for providing the scholarship for this research.

I would like also to thank my parents, brothers and sisters for all their love and support throughout the years. My endless love to my wife and our children: Riman, Abdurrahman and Raseel.

I would like also to express my thanks to a number of staff members of the Faculty of Health, Engineering and Sciences for various contributions made to this research:

- Associate Professor Brad Carter took the role of associate supervisor and made valuable contributions to the project design and provided valuable comments and suggestions;
- Dr Joanna Turner shared her experience in the field of UV dosimetery and contributed to the discussion regarding chemical UV dosimeters, and also assisted in proofreading and editing of the research proposal;
- Dr Nathan Downs provided valuable support in equipment training and calibration;
- Mr Oliver Kinder designed and constructed a number of precision mechanisms required for the experimental work;
- Mr Kim Larsen provided work space in the chemistry laboratory and assisted with the equipment required for the casting of the polymer films and also provided training and support relating to the FTIR spectroscopy; and
- Dr Kathryn Reardon-Smith contributed by proof reading and editing this dissertation and some of the related published papers.

Contents

Table of Figures

List of Tables